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**PRELIMINARY PLAN FOR TESTING A THERMIONIC REACTOR  
IN THE PLUM BROOK SPACE POWER FACILITY**

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# ABSTRACT

A preliminary plan is presented for testing a thermionic reactor in the Plum Brook Space Power Facility (SPF). A technical approach, cost estimate, manpower estimate, and schedule are presented to cover a 2 year full power reactor test.

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PRELIMINARY PLAN FOR TESTING A THERMIONIC REACTOR IN THE  
PLUM BROOK SPACE POWER FACILITY

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SUMMARY

A preliminary plan was prepared for testing a thermionic reactor at the NASA Space Power Facility (SPF). The SPF is located at the Plum Brook Station which is part of the Lewis Research Center. It was assumed that a sponsoring agency, the Space Nuclear Systems Office, would provide a reactor with a thermal output of 1500 kilowatts and an electrical output of 120 kilowatts. The Lewis Research Center would prepare the facility, provide all test support equipment and conduct a 2 year full power test.

A technical approach was established. Cost and manpower estimates, and a schedule were prepared. The total Lewis effort was shown to span 6 1/2 years, cost approximately 11 to 14 million dollars and require about 224 man years of engineering and technical manpower.

INTRODUCTION

A thermionic reactor development effort has been sponsored by the Space Nuclear Systems Office (SNSO) for the past several years. Prior to and during 1972, test sites were being evaluated for a reactor demonstration test. One of the possible test sites considered was the Space Power Facility (SPF) located at the Lewis Research Center's Plum Brook Station. A study was conducted to establish the technical feasibility, manpower and funding requirements, and scheduler aspects of the SPF test. The study was transmitted to the SNSO in three letters in mid 1972. This report presents the preliminary test plan developed through this study.

At the time of this study the reference reactor design had the following approximate characteristics:

Steady-state thermal power, 1500 kW  
Steady-state electrical power from thermionic fuel elements, 120 kW  
Coolant - liquid sodium-potassium (NaK 78)  
Coolant flow rate, 130 000 lb/hr (16.4 kg/sec)  
Core coolant outlet temperature, 1500° F (821° C)  
Core coolant  $\Delta T$ , 180° F (100° C)  
Fuel element sheath and reactor pressure vessel material, columbium -  
1% zirconium

Some important technical contributions were made to this study by the author's co-workers including: Preliminary hazards analysis by W. Maag,

preliminary heat transfer calculations by W. Weiland, and a preliminary shielding study by L. Soffer. The descriptive information on the SPF was excerpted from an informal document prepared by the SPF staff entitled, "Test Equipment Designer's Guide to SPF Capabilities."

#### APPROACH

The SNSO (through their contractors) would design, fabricate and deliver the thermionic reactor and reactor control system to the SPF. LeRC would design and procure the test support equipment and make the necessary modifications to the SPF capabilities and would set up, check out, conduct, and dismantle the test. The test would include 24 months of full power reactor operation.

The total LeRC-SPF effort would span 6 1/2 years. Scheduling would be keyed to the date specified for reactor delivery. The test support equipment would be on hand at the SPF and partially checked out at the time of reactor delivery.

The vacuum equipment, liquid metal cooling and supply systems, reactor and local shielding would be mated in the SPF Assembly Area and mounted on two special rail cars.

The test assembly would be rolled on existing tracks into the SPF test chamber for final hook up of controls and check out of all systems. The test would be controlled from the existing control room.

The test chamber atmosphere would be gaseous nitrogen ( $\text{GN}_2$ ) to minimize the chance for NaK fires. The local vacuum chambers would provide protection from oxidation to the reactor and primary loops which would be constructed of Cb-1Zr. The secondary loops would be constructed principally of stainless steel.

The reactor would be cooled by NaK circulating in a dual system consisting of two primary loops, two intermediate heat exchangers and two secondary loops. About 85 percent of the thermal load would be rejected via radiators from the secondary loops and absorbed by an existing facility cold wall. The other mode of heat rejection would be conduction through the  $\text{GN}_2$  to the facility chamber walls.

The electrical power output from the thermionic fuel elements (TFE's) would be dissipated to a water cooled resistance load.

Following completion of the 24 month full power test and about 2 weeks for decay of radioactivity, the test assembly would be rolled out of the Test Chamber into the SPF Disassembly Area. The spent reactor would be placed in hot storage or shipped to a disassembly site as specified by the sponsoring agency.

## SPACE POWER FACILITY (SPF)

The SPF is located at the Plum Brook Station of the NASA Lewis Research Center, Sandusky, Ohio. The SPF is designed to test space nuclear power generation and/or propulsion systems under simulated space environmental conditions including vacuum, thermal, and nuclear conditions.

Figure 1 shows the general arrangement of the SPF. The SPF includes an aluminum test chamber surrounded by a heavy concrete and steel enclosure for nuclear shielding and containment, facilities for assembly and disassembly of experiments, a large scale vacuum system, control and data acquisition systems and supporting facilities. A cross section of the test chamber is shown in figure 2.

### Test Chamber

The test chamber is a vertical cylinder 100 feet (30.5 m) in diameter by 72 feet (21.9 m) in height with a hemispherical dome, the top of which is 121 feet (36.9 m) above the floor of the chamber. The chamber is constructed of type 5083 aluminum which is clad on both surfaces with 1/8 inch (0.31 cm) thick type 3003 aluminum. The vertical walls are 7/8 inch (2.2 cm) thick while the dome is of 1 1/4 inch (3.1 cm) thick aluminum plate.

The entire aluminum test chamber is designed to withstand structurally, with a safety factor of 2, a pressure surge of approximately 3.1 psi (2.1 N/cm<sup>2</sup>) and also to withstand an external static pressure equivalent to 2.5 psi (1.7 N/cm<sup>2</sup>) applied uniformly to all exterior surfaces. A burst disk between the annular space and the test chamber is set to prevent this pressure differential from exceeding 2.5 psi (1.7 N/cm<sup>2</sup>).

The chamber has two 50 by 50 feet (15.2 by 15.2 m) electrically operated aluminum doors located 180° apart. These doors provide entry to the assembly and disassembly areas. The doors are curved to fit the cylindrical shape of the test chamber and are double sealed. Pneumatically operated locking mechanisms are provided to fasten the doors to the test chamber for leak tight pressure and vacuum operation.

Other features of the test chamber include an airlock, a polar crane, a clear 50-foot (15.2-m) floor width working section and a full complement of service penetrations. The chamber floor is heavily braced to withstand a load of 200 tons (181 436 kg).

The test chamber is designed to provide an ultimate vacuum of  $1 \times 10^{-5}$  torr ( $1.33 \times 10^{-3}$  N/m<sup>2</sup>) or  $1 \times 10^{-8}$  torr ( $1.33 \times 10^{-6}$  N/m<sup>2</sup>) with the thermal shroud. The test chamber is resistant to corrosive vapors (in limited quantities) and to the radiation environment of a test vehicle nuclear system and large thermal loads as delineated below:

- (a) Temperature: -300° to +180° F (-184° to +82° C) (with use of thermal shroud)

(b) Pressure: Atmospheric to  $1 \times 10^{-8}$  torr ( $1.33 \times 10^{-6}$  N/m<sup>2</sup>)

(c) Nuclear radiation at a distance of 10 feet from a source equivalent to the following radiation levels:

Gamma:  $1.7 \times 10^5$  r/hr or  $3.6 \times 10^8$  r/90 days

Fast Neutron:  $8.3 \times 10^9$  n/cm<sup>2</sup> - sec or  $6.4 \times 10^{16}$  n/cm<sup>2</sup> - 90 days

(d) Vapors: NaK, mercury, or cesium

The test chamber includes a movable, water cooled cold wall with cylindrical dimensions of 40 feet (12.2 m) diameter by 40 feet (12.2 m) high.

A 20-ton (18 142-kg) overhead crane is provided which may be removed during testing.

#### Test Chamber Enclosure

The functions of the test chamber enclosure are to provide a nuclear radiation shield, to contain the pressure during a maximum credible accident (MCA), and to protect an evacuated test chamber from atmospheric pressure.

The test chamber enclosure is a concrete enclosure 130 feet (39.6 m) in inside diameter which is 7 feet (2.1 m) thick around the cylindrical portion and 6 feet (1.8 m) thick over the dome. It is 150 feet (45.7 m) high inside on the vertical center line from the top of the base slab.

There is a 15-foot (4.6-m) wide annulus between the concrete enclosure and the test chamber exterior surface which can be evacuated to a pressure of 25 torr ( $3.3 \times 10^3$  N/m<sup>2</sup>). The chamber annulus is designed for the following environmental conditions:

(a) Pressure: Atmospheric to 25 torr ( $3.3 \times 10^3$  N/m<sup>2</sup>)

(b) Nuclear radiation at a distance of 25 feet (7.6 m) from an unshielded reactor core having the following radiation levels:

Gamma:  $2.7 \times 10^4$  r/hr or  $5.8 \times 10^7$  r/10 days

Fast Neutron:  $1.3 \times 10^9$  n/cm<sup>2</sup> - sec or  $1 \times 10^{16}$  n/cm<sup>2</sup> - 90 days

Two hydraulically operated concrete doors 50 feet (15.2 m) wide by 50 feet (15.2 m) high by 7 feet (2.1 m) thick, weighing 5 million pounds (2.3 million kg) each, are provided opening onto the assembly and disassembly areas.

The test chamber enclosure is designed to contain, with a safety factor of 2, internal pressures from 25 torr to 22.7 psi ( $3.3 \times 10^3$  to  $15.6 \times 10^4$  N/m<sup>2</sup>). The interior surface of the concrete, with the exception of the dome area,

is covered by a 4-inch (10-cm) layer of borated concrete to minimize neutron activation of the shield structure. A continuous 1/4 inch (0.62 cm) thick steel membrane is embedded in the concrete envelope. This membrane provides further containment against the possible release of radioactive materials which might result from a nuclear accident within the test chamber. It also provides vacuum integrity for the partial evacuation of the annular region between the concrete shield and the test chamber.

A personnel airlock penetrates the concrete enclosure matching a test chamber airlock. The airlock is sized to allow entry of a tread mounted robot manipulator. Other penetrations are provided for services such as electrical and control wiring, fluids, repressurization gas system and the vacuum system. The penetrations are located below ground level for shielding purposes. All penetrations are welded. Expansion points are provided as necessary. Wiring penetrations utilize leak tight multi-pin connectors. Two isolation valves in series are provided in all penetrating piping systems. The valves are designed for automatic operation by a high radiation level in the stack effluent thus containing the radiation sources within the chamber. The maximum design leakage from the test chamber enclosure with penetrations blind flanged and doors seal-welded, and with an 22.7 psi ( $15.6 \times 10^4$  N/m<sup>2</sup>) internal pressure is 0.1 percent of the total contained gas per day.

Three television monitors in the test control center can display pictures from three cameras in the chamber located approximately 120° apart in a horizontal plane. Each camera is controllable over 0° to 335° pan, 0° to 45° tilt, and has a zoom lens. Each camera includes a special spotlight aligned with the camera lens for illumination of the viewing area.

#### Assembly Area

The assembly area is a steel frame building 75 feet (22.9 m) wide by 150 feet (45.7 m) long with a clear height of 88 feet (26.8 m) to the roof trusses. The area is equipped with a 25-ton (22 678-kg) overhead bridge crane serving the entire length of the building and three sets of railroad tracks which extend through the test chamber and into the disassembly area. The structure is designed to accommodate a future 75-ton (68 032-kg) crane.

#### Disassembly Area

The disassembly area provides a space 70 feet (21.3 m) wide by 150 feet (45.7 m) long with a clear height of 73 feet (22.3 m) for remote disassembly, cut-up, and disposal of nuclear spacecraft systems after completion of the environmental test. The structure is constructed of concrete (varying in thickness from 6 ft (1.8 m) in the walls to 4 ft (1.2 m) in the roof) to provide shielding of personnel from gamma radiation from the radioactive test articles. A hot cell is provided within this area for remote examination of nuclear reactors and components.

The building is provided with a 20-ton (18 142-kg) overhead bridge crane.

The design allows for the future addition of an overhead bridge manipulator and two wall type manipulators, one on each side of the building. Remote operation of this equipment will be from exterior galleries along the sides of the building utilizing lead glass shielding view windows spaced to provide complete visual coverage of the operation within the building.

#### THERMIONIC REACTOR TEST SETUP

The arrangement of major test equipment is shown schematically in figure 3. Equipment items to be supplied by Lewis-SPF are listed in table I. Equipment is required in the following categories:

- (1) Reactor system (and controls)
- (2) Rail flat cars
- (3) Liquid metal cooling, storage, and purification systems
- (4) Local vacuum systems
- (5) Local shielding
- (6) Test control and diagnostic instrumentation
- (7) Spent reactor shipping cask
- (8) Facility heat rejection and remote handling systems

#### Protection of Cb-1Zr

Special consideration was given to the need for protecting the Cb-1Zr from oxidation and corrosion in this long-term, high-temperature test. The precautions to protect against these effects impact heavily on the test setup and cost. These include:

(1) Protection of internal surfaces in contact with the reactor primary coolant NaK: The detrimental effects of corrosion include the loss of properties and mass transfer which can lead to plugging of coolant passages. Although present knowledge does not allow for accurate prediction of these effects in a given loop it does allow for design to hold them to safe levels. This plan calls for observance of the following three criteria:

(a) Within a given high-temperature loop the containment equipment in contact with the NaK shall be fabricated from a single material. In this test the primary loop material shall be of Cb-1Zr to match the reactor pressure vessel and fuel element sheath tubes. The secondary loops (lower temperatures) shall be constructed primarily from stainless steels.



(b) The oxygen contamination level in the NaK shall be controlled to not greater than 10 ppm during long test periods.

(c) The impurity level shall be controlled in containment materials in accordance with specifications to be detailed later.

(2) Protection of external surfaces of Cb-1Zr in contact with the test ambient environment: These surfaces must be protected against oxidizing environments to prevent embrittlement and loss of properties. This plan provides this protection by isolating the Cb-1Zr material from the SPF test chamber environment by enclosing the primary loop in vacuum chambers with suitably low oxidizing potential. Experience in other programs (ref. 1) has shown that adequate protection of Cb-1Zr is provided when the oxygen partial pressure ( $PO_2$ ) is controlled to approximately  $1 \times 10^{-10}$  torr ( $1.33 \times 10^{-8}$  N/m<sup>2</sup>). This  $PO_2$  level can be maintained by pumping to a total pressure of approximately  $1 \times 10^{-8}$  torr ( $1.33 \times 10^{-6}$  N/m<sup>2</sup>) provided the pumping equipment does not contribute reactive species to the pumped region. The vacuum systems included in this plan meet these criteria and are similar to those used in the reference 1 program. Each of the three vacuum pumping systems shall include:

(a) Turbo-molecular pumps for high pumping speeds of all species during bakeouts and pumpdowns.

(b) Ion pumps for the long term pumping of all species to maintain  $10^{-8}$  torr ( $1.33 \times 10^{-6}$  N/m<sup>2</sup>). Redundant pumps shall be provided.

(c) Titanium sublimation pumps to remove reactive species during periods of sporadically high off-gassing.

Vacuum will be monitored with ion gages and by monitoring the ion pump currents.

#### Heat Rejection Systems

This plan calls for two parallel heat rejection systems with a total flow rate in the primary loops of 130 000 pounds per hour (16.4 kg/sec). Each system would be sized to remove 50 percent of the total thermal heat load of 1500 kilowatts. Both systems would be flowing during normal operations. In the event of a leak in one system the isolation valves for that system would be closed and the reactor scrammed. Uninterrupted flow would be provided by the remaining system to cool the shutdown core. Isolation valves would serve to prevent gross leakage and would not be required to provide 100 percent sealing. This is a realistic capability for valves with refractory metal seating materials.

Other safety design aspects of the heat rejection systems would include design for convective flow and provisions for partial emergency power to the

pumps in the event that main facility power is lost. As previously mentioned the SPF environment external to the local vacuum chambers would be  $\text{GN}_2$  to minimize the chance of NaK fires. This nitrogen could also be used as a coolant for the electromagnetic pumps, flow meters, and test support vacuum pumps.

Some aspects of the heat rejection system are directed toward minimizing the size of the refractory metal loops. Intermediate heat exchangers (IHX's) are included. The IHX's are designed to maintain the secondary loops about  $300^\circ\text{F}$  ( $167^\circ\text{C}$ ) cooler than the primary loops. This will allow the secondary loops, including long lines and radiators, to be fabricated of stainless steel. If the final reactor design outlet temperature is actually less than  $1500^\circ\text{F}$  ( $821^\circ\text{C}$ ) (e.g.,  $1400^\circ\text{F}$  ( $760^\circ\text{C}$ )) this can be accommodated without lowering the radiator temperature by adjusting the conductivity across the IHX's. One means of doing this would be to include a binary gas gap between the Cb-1Zr and stainless steel surfaces. Conductivity could be controlled by adjustments of the gas mixture (e.g., a He-Ze system).

Approximately 85 percent of the total thermal heat load will be expelled through the radiators and absorbed by the facility cold wall (existing). This heat is removed from the facility by a circulating water system. The other mode of heat transfer is convective cooling by the environmental nitrogen. This heat is eventually conducted out through the test chamber walls. Preliminary calculations indicate the steady-state average temperature of the  $\text{N}_2$  to be approximately  $155^\circ\text{F}$  ( $68^\circ\text{C}$ ) and the aluminum chamber walls to be approximately  $115^\circ\text{F}$  ( $46^\circ\text{C}$ ). Additional cooling capability will be provided for the dissipation of heat from a resistance electric load of about 120 kWe and possibly for cooling the local concrete shield to control dehydration.

### Local Shielding

A preliminary study was conducted to establish the approximate local shielding requirements. Nominal equipment compositions and weights were used. Plots were constructed of maximum radiation level at the local shield outer surface following reactor shutdown. Three radiation sources would be contributing: core decay gammas, radioactive primary NaK, and radioactive components. It was assumed that no fission products would be present in the primary NaK. Figure 4 shows plots of radiation level against shield thickness for various decay times. It was concluded that with 4 feet (1.2 m) of local concrete shielding personnel could enter the test chamber for manual work about 14 days after reactor shutdown. As indicated in figure 3 multiple vacuum chambers would be used rather than one large chamber. This would facilitate pumping and would also allow the core shield to be smaller and to protect most of the test support equipment.

## TEST OPERATION SEQUENCE

A step-by-step sequence of planned events is listed below.

- (1) SPF facility handling equipment procured and installed. Facility water cooling system upgraded from present 1 megawatt capability to approximate 2 megawatt capability.
- (2) Liquid metal heat rejection system components procured and inspected.
- (3) Special flat car assembled in SPF assembly area.
- (4) Vacuum systems and shield installed on flat car.
- (5) Liquid metal heat rejection system mounted on test support structure and structure mounted on flat car.
- (6) Reactor, controls, and instrumentation delivered to SPF assembly area.
- (7) Instrumentation installed in control room.
- (8) Reactor (without reflector drums) installed in vacuum tank and shield and secured according to mounting flange design. (Piping stubs, instrumentation leads, and electrical load conductor are arranged to penetrate the shield.)
- (9) NaK heat rejection system piping manually welded to reactor piping stubs and other interconnections made between vacuum tanks.
- (10) Entire NaK system cleaned and back filled with inert gas. NaK inventory stored in drain and fill tank.
- (11) Flat car rolled on rail tracks from assembly area into SPF test chamber and secured to chamber floor.
- (12) Electrical hookup and test support equipment water and nitrogen hookups completed.
- (13) NaK system charged by pressurizing the NaK tank. Purity levels checked with system being heated by electrical heater. All mechanical test support equipment checked out.
- (14) With system again at room temperature, the reflector drums are manually installed and the local shield and vacuum tank are closed.
- (15) SPF cold wall assembled around radiators. Cold wall circulation checked.
- (16) Chamber cleared, sealed, evacuated, and back filled with  $N_2$  gas. (Evacuation will not be prolonged because off-gassing is not essential (and

probably not practical with the concrete shielding present). This procedure will require about 48 hr.)

(17) Local vacuum chambers baked out and test vacuum achieved.

(18) Water circulation in cold wall established.

(19) Reactor nuclear check out and low power runs accomplished. Television surveillance provided.

(20) Full power testing accomplished. (This is the long term (24 month) test.) Television surveillance provided.

(21) Following test completion, system NaK is again transferred to the NaK tank.

(22) Radioactive NaK allowed to decay. Test chamber again evacuated with effluent gas passing through absolute particle filters and gas absorbers. Effluent gas activity monitored and pumping rate adjusted if necessary to meet release criteria.

(23) Following evacuation, chamber back filled with air. Personnel enter and manually disconnect water and instrumentation lines. (Radiation levels are anticipated to be low enough to permit personnel to accomplish this work after the reactor has been shut down for 14 days.)

(24) System moved to hot disassembly area.

(25) Shield and vacuum tank opened. (A 20-ton (18 142 kg) crane, remote handling equipment, and remote operation viewing stations are available in this area. A special hot cell is accessible from this area.)

(26) Reflector drums removed from reactor and reactor loaded into the transfer cask for shipment or stored in the facility hot storage pit as required.

#### PRELIMINARY HAZARDS ANALYSIS

A preliminary analysis of the hazards of operating a thermionic reactor in the SPF was prepared. This analysis indicates that the maximum credible accident (MCA) postulated for this test can be withstood provided the amount of NaK (or other reactive liquid metal) in the system is less than 1600 pounds (726 kg).

The MCA results from a nuclear excursion that occurs during a reactor startup after the reactor has been operated previously and therefore contains a full inventory of fission products. The MCA occurs while the SPF chambers still contain air at 40° F (4.4° C) and 14.2 psia (9.8 N/cm<sup>2</sup>) (atmospheric pressure at Plum Brook site). The SPF consists of an inner aluminum chamber of 890 000 cubic feet (25 200 m<sup>3</sup>) and an outer reinforced

concrete enclosure of 1 620 000 cubic feet (45 873 m<sup>3</sup>). The inner chamber is pressure rated at 3.1 psi (2.1 N/cm<sup>2</sup>) and the outer at 8.0 psi (5.5 N/cm<sup>2</sup>) above external conditions. The latter is designed for a maximum leak rate of 0.1 percent (by volume) per day at 8 psi (5.5 N/cm<sup>2</sup>) above external conditions. An allowable leak rate for the SPF has been calculated to be 0.2 percent per day based on a 15 megawatt reactor accident and the dose limits of 10 CFR 100.11.

The heat energy released by the MCA is assumed to be transferred to the chamber air which results in some maximum chamber pressure. The total energy release consists of: (1) the heat content of the NaK heat transfer fluid, (2) the exothermic heat of formation for the oxidation of NaK, and (3) the energy of the nuclear excursion which was assumed to be 1500 megawatt-second as reported in reference 2.

The results, presented in figure 5, show the chamber pressure resulting from the MCA as related to the total weight of NaK in the system. It is assumed the aluminum chamber ruptures and the resulting pressure refers to the concrete enclosure. At a NaK system weight of 1600 pounds (726 kg) the enclosure pressure reaches the maximum allowable 8.0 psi (5.5 N/cm<sup>2</sup>) above external conditions.

The system of figure 1 is assumed to contain a maximum of 1400 pounds (635 kg) of NaK. The MCA for this system would result in the following energy release and chamber conditions.

	Aluminum test chamber	Test chamber enclosure
NaK in system, lb (kg)	1400 (635)	1400 (635)
Chamber volume, ft <sup>3</sup> (m <sup>3</sup> )	890 000 (25 200)	1 620 000 (45 873)
Initial chamber temperature, °F (°C)	40 (4.4)	40 (4.4)
Initial chamber pressure, psia (N/cm <sup>2</sup> )	14.2 (9.8)	14.2 (9.8)
Air in chamber, lb-moles (kg-moles)	2350 (1066)	4290 (1946)
Heat release, M Btu (MJ)		
Heat content of NaK	604 (6.38x10 <sup>5</sup> )	604 (6.38x10 <sup>5</sup> )
Chemical reaction of NaK	5600 (5.91x10 <sup>6</sup> )	5600 (5.91x10 <sup>6</sup> )
Nuclear excursion	1420 (1.45x10 <sup>6</sup> )	1420 (1.45x10 <sup>6</sup> )
Total	7624 (8.05x10 <sup>6</sup> )	7624 (8.05x10 <sup>6</sup> )
Final chamber temperature, °F (°C)	503 (262)	294 (146)
Final chamber pressure, psia (N/cm <sup>2</sup> )	27.3 (18.8)	21.4 (14.8)

This MCA would rupture the burst disk between the test chamber and enclosure annulus and might rupture the test chamber. The enclosure would be expected

to contain the MCA so as to limit the total leak rate to less than 0.1 percent per day. As indicated above this is a safe leak rate for a 15 megawatt reactor accident and should therefore be very conservative for this 1.5 megawatt reactor test.

This preliminary analyses indicates that adequate safety margin exists to assure the containment of the MCA. However, it appears prudent that consideration should be given to altering the reference design to provide double containment of the core coolant. This would reduce the probability of a release of radioactivity within the facility in the event of a rupture of the primary reactor pressure vessel.

#### SCHEDULE

Figure 6 is an activity schedule for testing a thermionic reactor at SPF. This schedule indicates that a reactor could be accepted for installation about 3 1/2 years after the initiation of activity. The total Lewis-SPF effort for the test would require about 6 1/2 years assuming 2 years of uninterrupted, full power reactor operation.

#### COST ESTIMATE

Table I is an itemized estimate of cost of important test support equipment that would be provided by Lewis Research Center. Other major equipment cost such as facility modifications and remote handling equipment are included in SPF Preparation costs. These are listed in table II. Table II also lists the total Lewis-SPF estimated cost per year of effort for the thermionic reactor test at SPF.

#### MANPOWER REQUIREMENTS

The estimated Lewis-SPF manpower requirements per year of effort are listed in table III. The total requirement is approximately 224 man years of engineering and technical support spread over 6 1/2 years.

#### CONCLUDING REMARKS

It was concluded from this preliminary study that the SPF is a suitable test site for a thermionic reactor of the design being developed by the SNSO in 1972.

Since the reactor pressure vessel and primary loop piping would be fabricated from Cb-1Zr, a refractory metal alloy, local vacuum chambers would be required to protect these components from oxidation. The incorporation of intermediate heat exchangers and stainless steel secondary loops would help minimize the quantities of refractory material.

Facility modifications would be required to increase the cooling capacity of the existing water-circulation cold-wall system. Other major cost items include remote handling equipment, liquid metal cooling system, and a liquid metal handling system.

Test scheduling would be keyed to the reactor delivery. Facility preparations and test support equipment buildup would require about 3 1/2 years. The total activity for a single 2 year full power test would span about 6 1/2 years.

The test was estimated to cost about 11 to 14 million dollars based on 1972 rates. The total manpower requirement was estimated to be 224 man years of Lewis-SPF engineering and technical support.

#### REFERENCES

1. Hoffman, E. E.; and Holowach, J.: The Cb-lZr Rankine System Corrosion Test Loop. NASA CR-1509, 1970.
2. Anon.: Technical Information in Support of Thermionic Reactor Experiment Facility Cost Estimate. Rep. GESR-2123, General Electric Co., Feb. 1970.

TABLE I. - TEST SUPPORT EQUIPMENT COST

[Thousands of 1972 dollars.]

	Cost
Liquid metal system:	
NaK purification and storage equipment	550
Electro-magnetic pumps, EMP (4)	1000
Intermediate heat exchangers, IHX (2)	400
Radiators (2)	500
Flow meters (4)	18
Electric heaters (4)	40
Expansion reservoirs, RSVR (4)	500
Isolation valves (4)	120
Piping and insulation	40
Instrumentation and controls	300
Vacuum tanks and pump systems (3)	300
Experiment instrumentation	400
Component testing	700
Shielding	150
Test structures	100
Rail car	100
Electric load	25
Engineering studies	200
TSE total	5443



TABLE II. - TOTAL COST DISTRIBUTION FOR THERMIONIC REACTOR TEST AT SPF

[Costs in thousands of 1972 dollars.<sup>a</sup>]

Year of effort	1	2	3	4	5	6	7	Totals
SPF preparation	450	843	843	300				2 436
SPF operations direct & indirect				300	600	600	300	1 800
Test support equipment	1618	2203	1389	233				5 443
Research operations support	152	208	248	312	408	304	160	1 792
Totals	2220	3254	2480	1145	1008	904	460	11 471
Total cost plus 25 percent contingency								14 339

<sup>a</sup>1972 dollars are subject to yearly escalations depending on the date of initiation of effort.

TABLE III. - MANPOWER ESTIMATE FOR THERMIONIC REACTOR

## TEST AT SPF

Year of effort	Man-years						
	1	2	3	4	5	6	7
SPF							
Engineering	6	6	6	6	14	13	8
Technicians		4	8	16	25	25	12
Sub-total	6	10	14	22	39	38	20
LeRC (Engineering)	13	16	17	17	12		
Total man-years	19	26	31	39	51	38	20

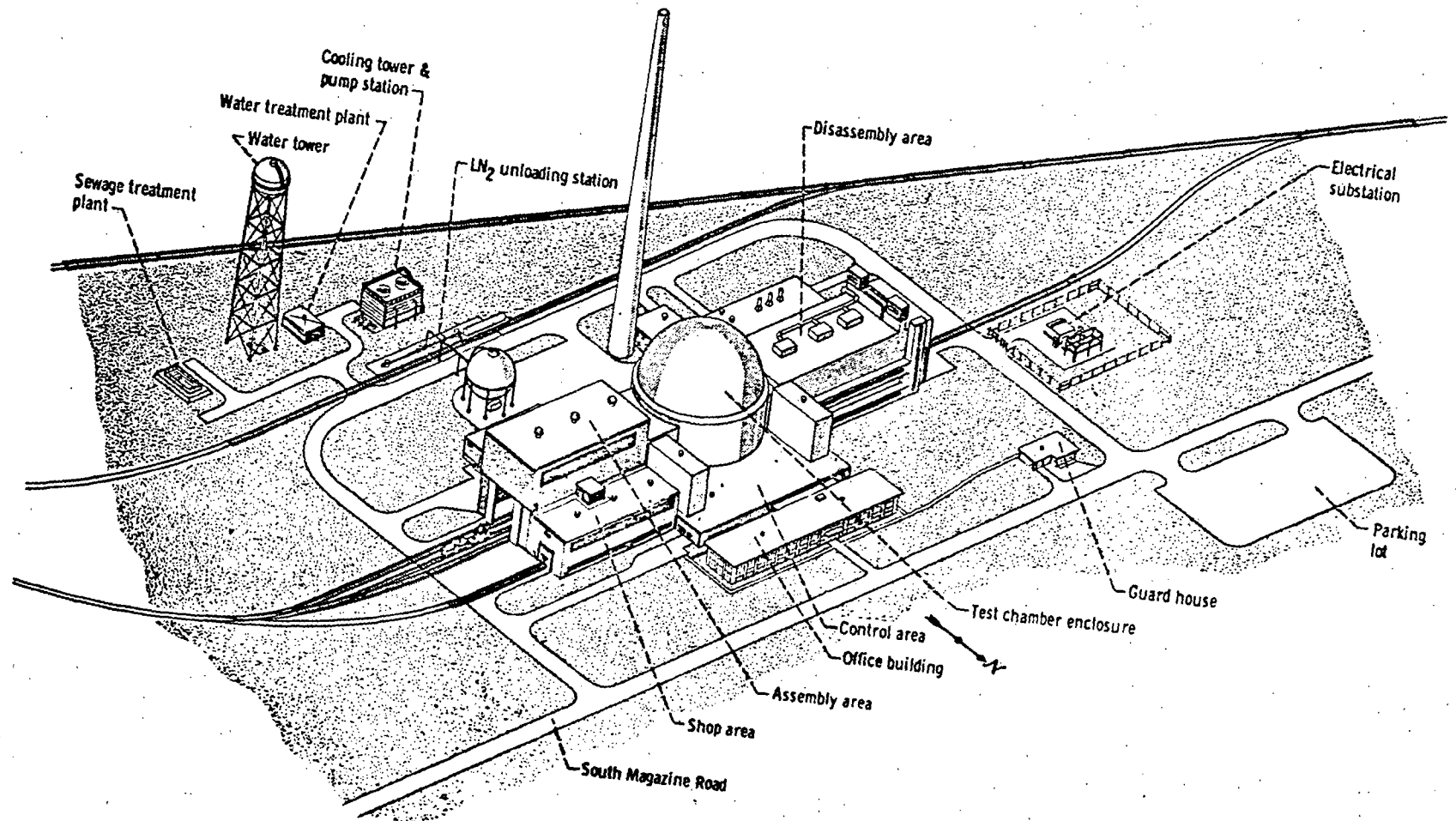
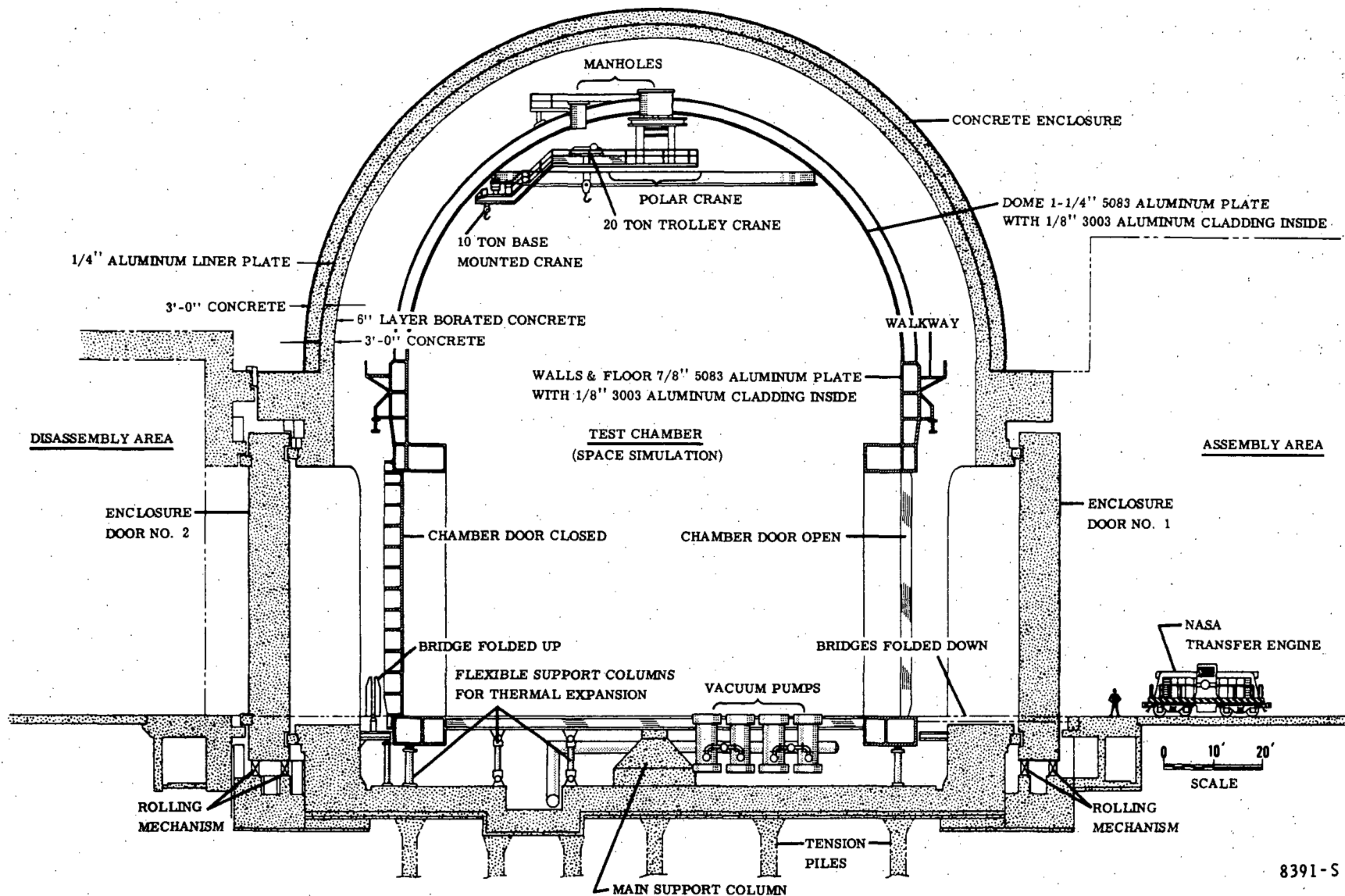


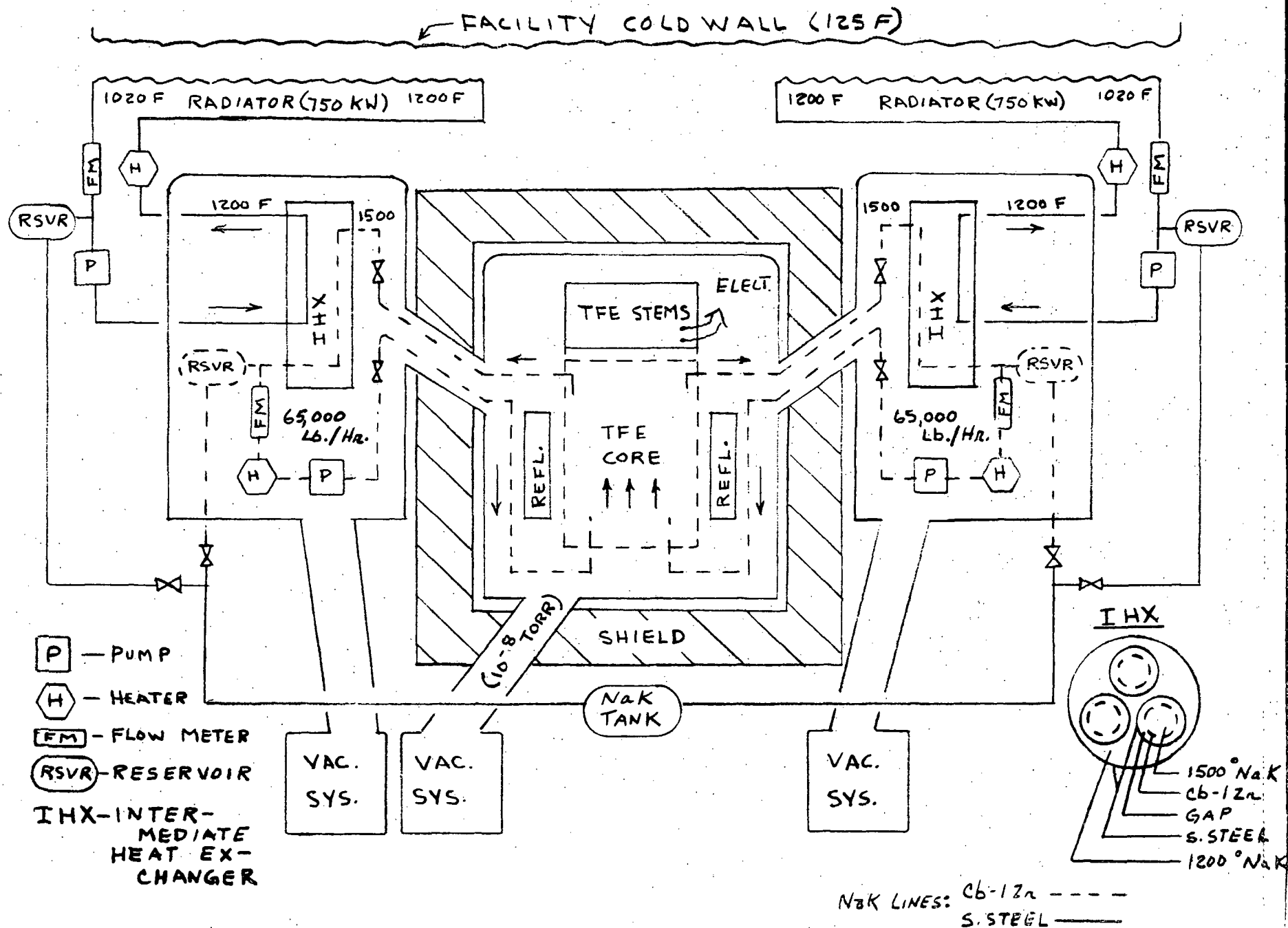
Fig. 1. General arrangement - Space Power Facility.



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Figure 2. - Cross section through Test Chamber - Space Power Facility.

FIG. 3 SCHEMATIC OF THERMIONIC REACTOR TEST IN SPF



GAMMA DOSE RATE, MR/HR

100

10

1

3.0

3.5

4.0

FT.

CONCRETE THICKNESS

8 DAYS AFTER SHUTDOWN

10 DAYS

12 DAYS

14 DAYS

FIG. 4 SHUTDOWN RADIATION LEVELS AT EXTERIOR SURFACE OF LOCAL SHIELD

1.0

1.1

1.2

IN.

FIG. 5 SPF CHAMBERS PRESSURES  
FOR MAXIMUM CREDIBLE  
ACCIDENT

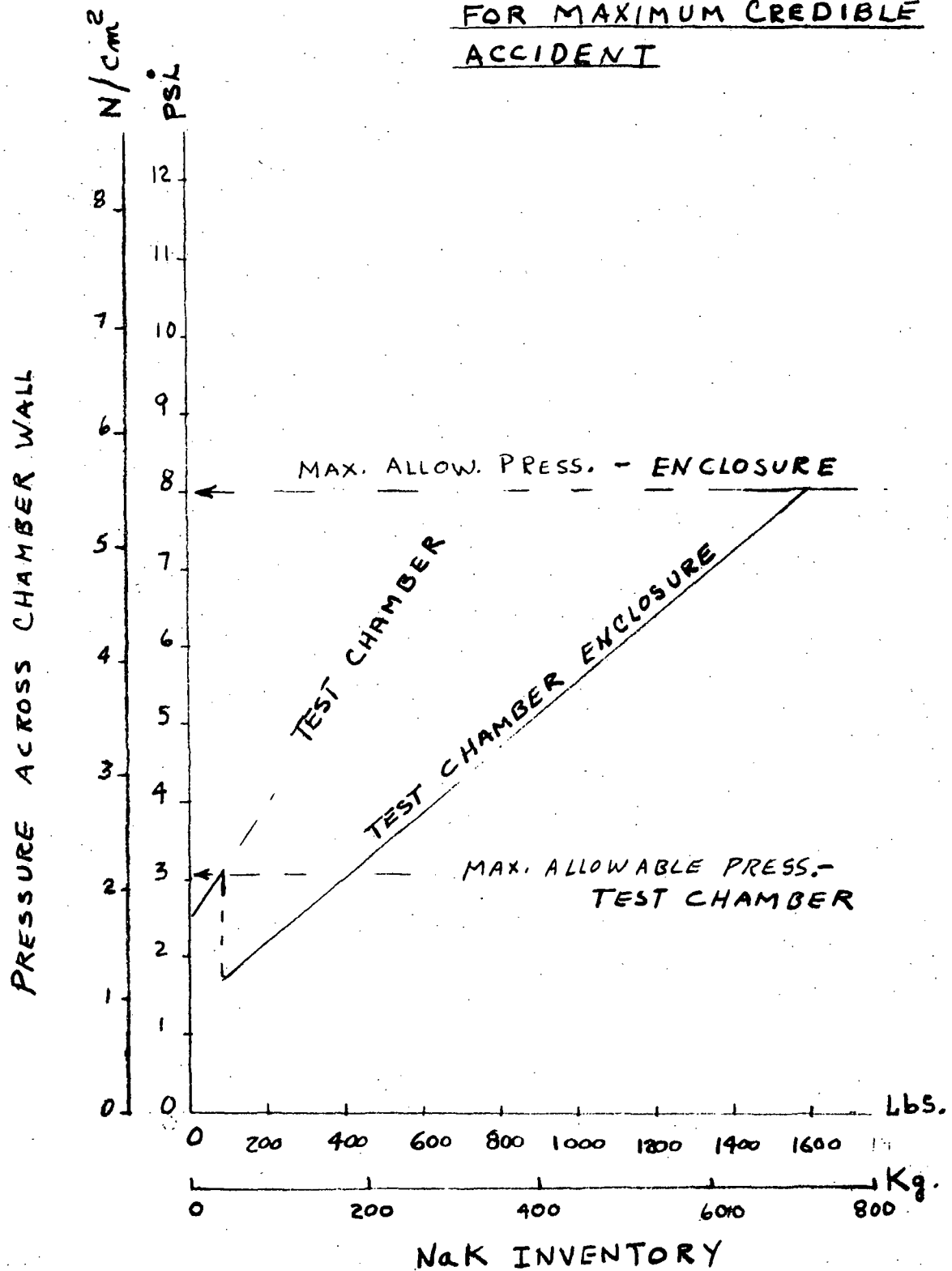


FIG. 6 SCHEDULE FOR  
THERMIONIC REACTOR TEST AT SPF

